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# THE SECOND PALOMAR SKY SURVEY

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## ABSTRACT

We describe the main characteristics of the second Palomar Observatory Sky Survey, currently being taken using the Oschin telescope on Palomar Mountain. The limiting magnitudes of the POSS II plates are directly comparable with those of the SERC/ESO southern surveys, at $B_J = 22.5$ mag, $R_c = 20.8$ mag, and $I_c = 19.5$ mag. We discuss the main modifications made to the telescope and the photographic methods employed in the course of the survey and compare the POSS I and POSS II plates.

*Key words:* photographic sky survey

## 1. Introduction

The photographic sky surveys produced by large Schmidt telescopes have proved to be among the most useful and enduring weapons in the astronomical armory, both as reference catalogs for source identification and as powerful tools of research in their own right. The first of these surveys, the National Geographic Society-Palomar Observatory Sky Survey (hereinafter POSS I), was started in early 1949 using the year-old 48-inch (1.2-m) Oschin telescope, at that time the largest Schmidt telescope in existence. While Baade and Wilson were among the early advocates of the project, the survey was brought to completion largely under the auspices of Minkowski and Abell, who in 1953 assumed responsibility for acquiring high-quality plates. Initially used with considerable success for the optical identification of the sources identified by the fledgling science of radio astronomy (Minkowski & Baade 1954), these plates formed the basis of numerous surveys, most notably Abell's catalog of galaxy clusters (Abell 1958) and, combined with second-epoch plates taken with the Oschin Schmidt telescope between 1961 and 1970, Luyten's proper-motion surveys (Luyten 1963).

The original sky survey was taken using Kodak 103a emulsions. The intervening years have seen considerable developments in both the resolution and spectral sensitivity of photographic emulsions and in the technology of hypersensitization. These improvements have been illustrated most dramatically by the high-quality plate material produced by both the 48-inch (1.2-m) UK Schmidt Telescope, whose mechanical design was modeled closely on the Oschin Schmidt, and the 1-m ESO Schmidt at La Silla, Chile. The southern sky surveys produced by these telescopes using the fine-grain IIIa emulsions extend 2–3 magnitudes deeper (in the blue) and have higher resolution than the northern POSS I. Moreover, the construction of an achromatic corrector, providing excellent image quality at wavelengths beyond 6500 Å, allowed the UK Schmidt Telescope to extend these surveys to the near-infrared ($\lambda \sim 8500$ Å).

Given these evident technological improvements, it was decided that a new survey of the northern sky should be undertaken. The full success of this project required substantial upgrading of both the telescope and the photographic facilities, funded by the California Institute of Technology and by grants from the National Science Foundation, the National Geographic Society, Eastman-Kodak, the Samuel Oschin Foundation, and the Sloan foundation, while Kodak is also providing the photographic plate material. The survey is now well under way, with coverage of more than 40% of the sky in the IIIa-J/IIIa-F passbands. In this paper we take the opportunity to outline the modifications that have been made to the Oschin Schmidt and to describe the characteristics of the current survey material. Section 2 outlines the overall plan of the current survey, POSS II; in Section 3 we describe the modifications made to the telescope; Section 4 discusses the plate hypersensitizing and processing techniques; and the plate quality is described and illustrated in Section 5.

## 2. The Survey

The original sky survey is described in detail by Minkowski & Abell (1963, hereinafter MA63), but we summarize briefly here the main points. POSS I was designed originally to cover the sky with blue and red plate pairs to a declination limit of $-27°$ (Wilson 1952) but was extended to $-33°$ after it became apparent that it

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was possible to obtain plates of sufficiently high quality at these low altitudes. With relatively short exposure times (20 minutes in the blue, 40 minutes in the red), the plate pairs were taken on the same night, with the first accepted plates being taken in July 1949 and the survey completed in late 1956. Whiteoak further extended the survey to a declination of $-45°$ (or a zenith distance of 78°) using red plates only.

The original survey was taken with a six-degree spacing between plate centers. While this allowed coverage of the sky in only 935 plate pairs (879 to $-27°$), the $6° \times 6°$ field covered by the 14-inch plates allows only a small overlap between adjacent fields, with most of this overlap lying in the vignetted regions. For the POSS II we have followed the example of the SERC/ESO southern surveys and adopted a five-degree field spacing. The latter surveys now cover the entire southern celestial hemisphere, and, in consequence, we can restrict the current survey to the 894 fields north of (and including) the celestial equator. Thus, both surveys cover the 72 fields at 0° declination.

Eastman Kodak type-103a emulsions were used for both red and blue plates of the POSS I, with the blue plates being unfiltered 103a-O and the red plates combining 103a-E emulsion with a red plexiglass 2444 filter. The resultant spectral response functions (see MA63) give effective wavelengths of ~ 4100 Å in the blue (with a passband of ~ 1100 Å) and ~ 6500 Å in the red (passband ~ 500 Å). The current survey is being taken in three passbands: blue (IIIa-J emulsion and GG395 filter —$\lambda_{eff}$ ~ 4800 Å); red (IIIa-F and RG610—$\lambda_{eff}$ ~ 6500 Å), and in the near-infrared (IVN and RG9—$\lambda_{eff}$ ~ 8500 Å). The J and F passbands avoid the strong Na D emission generated by low-pressure sodium lighting. Figure 1 plots the spectral response (relative to a source with $I(\lambda)$ = constant) for these three filter/emulsion combinations. In each case the blue limit is filter-defined, while the red limit is set by the response of the emulsion.

The 103a emulsion is a moderately coarse-grained emulsion, with a resolution of 80 lines mm$^{-1}$, but with high contrast. Both the type-IIIa and the IVN emulsions have a higher contrast (photographic gamma) and have three times the resolving power, at 250 lines mm$^{-1}$. The smaller grain size leads to significantly higher uniformity in the sky background of the modern plates and a correspondingly increased ability to detect objects of low surface brightness. The effective gain for astronomical purposes is discussed in Section 5.

In addition to sky-limiting exposures in the J, F, and N passbands, short-exposure (3-minute) unhypered IIIa-J plates are also being taken of each POSS II field. These plates have been provided by the U.S. Naval Observatory to allow accurate astrometry of the bright fundamental reference stars and fainter (12–13 magnitude) secondary reference stars on the same plates. The latter stars will then be used to tie together the reference frames defined by the (transit circle-observed) fundamental stars and the (radio-observed) extragalactic objects.

## 3. The Oschin Telescope

The Oschin 48-inch (1.2-m) Schmidt camera is situated on Palomar Mountain at an altitude of 1700 meters and at coordinates 33°21′26.″35 north, 116°51′32.″04 west. The

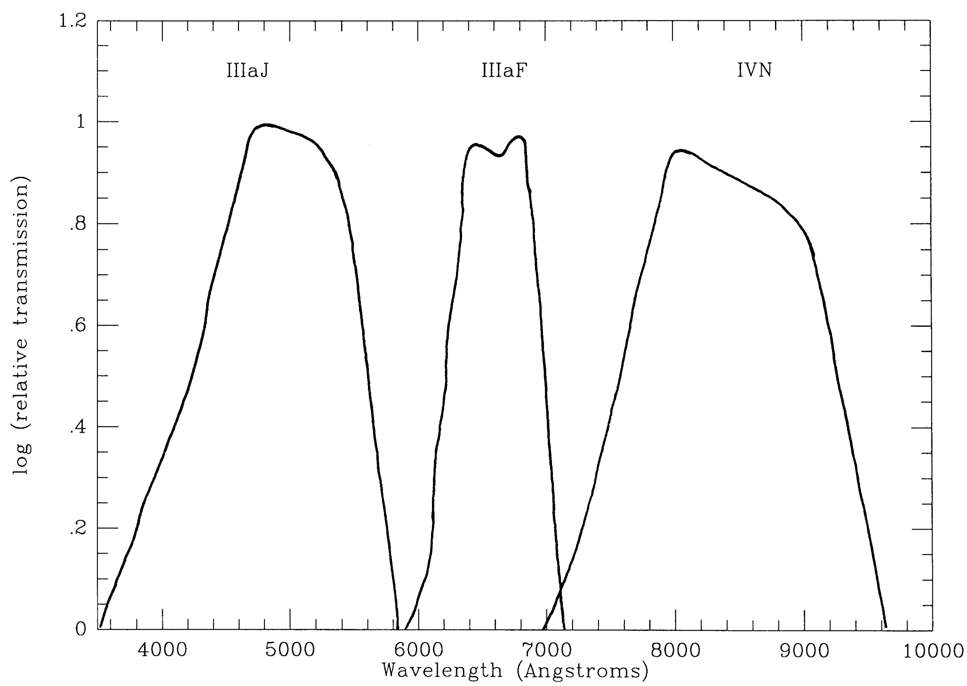


FIG. 1–The spectral response of the three passbands of the new Palomar Sky Survey.

primary mirror is of diameter 72 inches (1.8 m) with a radius of curvature of 241 inches. The correcting plate has a clear aperture of 49.5 inches and the effective focal length of the system is 121 inches, giving a focal ratio of $f/2.44$ and a plate scale of 67.″19 per millimeter. Although the 14 × 14 inch plates cover 6.°6 × 6.°6 on the sky, the unvignetted field is of only 5.°4 diameter.

Harrington 1952 has described the optical and mechanical characteristics of the telescope in its original incarnation. As mentioned in the Introduction, numerous modifications and improvements have been made to the telescope throughout the progress of the present survey, many prompted by the higher quality of the current plate material, but mechanically the telescope remains little changed. Thus, while worn bearings and other moving parts have been replaced, the mirror support system and telescope drive remain largely as described by Harrington. In this section we outline the major alterations that have been made.

### 3.1 *The Corrector Lens*

The original corrector plate is of plate glass, figured to give the minimum chromatic aberration at λ4358 (MA63). As a result, the image quality deteriorates significantly at near-infrared wavelengths, as is apparent from a comparison between the POSS I red plates and the plates taken for the near-infrared Galactic plane survey (Hoessel et al. 1979). A new achromatic corrector plate was constructed by Grubb Parsons and installed in the telescope in 1985. This lens, made to the same design as the UK Schmidt Telescope (UKST) achromat described by Wynne 1981, is a doublet in construction, combining Schott type-LLF6 glass with O'Hara BK7W (equivalent to Schott UBK7). The resultant image size is better than 0.″5 for in-focus point sources over the full 6.5 × 6.5 degree field for 3900 ≤ λ ≤ 9000 Å.

The corrector, however, has a significant astigmatic component. For in-focus images the circle of confusion is only 0.″34 in diameter, and the image size is determined by the seeing disk. However, moving as little as 30 μm outside the image plane leads to significant image elongation, as Figure 2, taken from a focus plate, illustrates. This sets stringent criteria on the rigidity of the plate-holder assembly, criteria which the original construction failed to meet, leading to the modifications described below. The UKST corrector is similarly astigmatic, but their plate material is affected to a lesser extent, mainly through their having a more rigid defining system but also because poorer seeing (2 arc seconds or worse) masks small departures from the focal plane.

### 3.2 *The Plate Holders*

In a classical Schmidt telescope the focal plane is a spherical surface with a radius of curvature equivalent to the focal length of the telescope—in the case of the Oschin Schmidt, 120.9 inches (3.07 m). The 1-mm thick glass plates are bent to shape by the plate-holder mandrels (Harrington 1952, Fig. 4). However, with no further assistance, the flat glass plate does not conform to a spherical surface with complete accuracy, with deviations of up

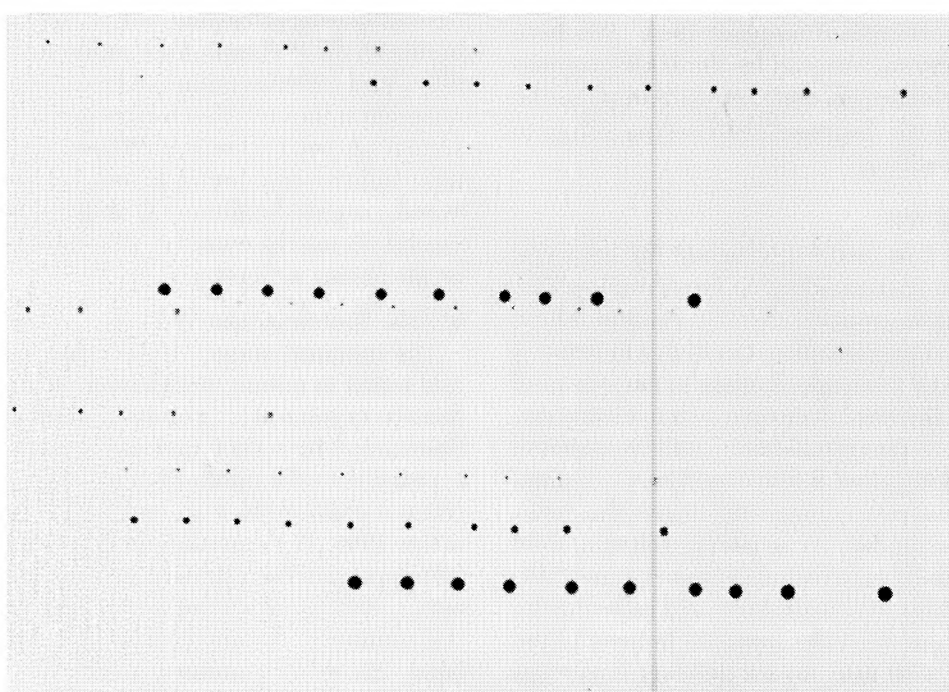

FIG. 2–Images from a focus plate taken with the 48-inch (1.2-m) Oschin Schmidt. The astigmatism present in the corrector produces north-south elongation on one side of the focus and east-west elongation on the other side. The focus step-size is 30 microns.

to 50 μm. The astigmatism present in the corrector leads to images having significant elongation. To compensate for this effect we have, following the UKST, installed a vacuum system to force the plates to conform to the spherical surface of the mandrel. Holes were drilled ~ 10 cm in from the midpoint of each side and connected by a 50-μm wide, 25-μm deep groove in the neoprene. Running at a pressure of 430 mm of mercury, this forces the plate to conform to the figured mandrel to an accuracy of ± 15 μm.

While installing this system it became apparent that the mandrels had been figured to a smaller radius of curvature than the focal length of the telescope—typically 120.4 inches—presumably in an effort to compensate for the effect of the trapped air pockets. All of the mandrels have been reground to the correct radius of curvature. At the same time, the neoprene facing in the mandrel was replaced by conductive teflon. The refigured plateholders deviate by no more than ~ 15 μm from the required spherical surface.

Finally, tests made on the UK Schmidt Telescope have shown that IIIa-F and IIIa-J plates lose sensitivity if left in a humid atmosphere. Moreover, the plateholders currently in use with the survey have the filters installed directly (as at UKST), rather than in a separate bracket in the telescope, with the clearance between plate and filter varying from ~ 2 mm at the plate center to more than 20 mm at the edge. If not compensated for, this arrangement leads to a greater desensitizing near the edges of the plates (where there is more air and more water vapor) and noticeable nonuniformities (Campbell 1982). We have followed the procedures adopted by the UKST to compensate for this problem, flushing nitrogen through the plateholder during the exposure of IIIa-type plates to maintain a dry atmosphere.

### 3.3 *The Defining Frame*

The plateholder is located in position in the telescope by three defining points mounted on the central spider. As noted above, tests revealed that the original frame, made of ASTM 14 aluminum alloy, flexed as a function of the orientation of the telescope, leading to movement of up to 50 μm from the focal plane and astigmatically distorted images. While the plateholders could be shimmed to compensate within a given declination zone as a temporary palliative, it was clearly important to give the defining frame increased rigidity. As an interim solution, solid aluminum box sections were bolted in place in June 1989, increasing the stiffness by a factor three and reducing the change in tilt (moving from the southern horizon to the pole) to less than ± 10 μm. A new defining frame was designed by H. Petrie and installed in the telescope in early October 1989. The flexure is now reduced to ± 5 μm. At the same time, the defining blocks, which had become worn through 40 years of use, were replaced with a slightly modified design.

### 3.4 *The Autoguider*

Plates taken in the original survey were all hand guided using the two 10-inch refractors mounted on the main telescope. Given the longer exposure times of the current survey (60–70 minutes J,F; 80–90 minutes N), we have replaced the eyepiece unit on the southern guidescope with an autoguider. This is patterned after the instrument originally designed by Gunn for the 4-Shooter CCD camera on the Hale 200 inch (5 m) (Gunn et al. 1987). (4-Shooter currently uses a modified system.) The photomultiplier is mounted behind a rotating knife edge and the signal is monitored as a function of phase. Equal signal indicates that the star is centered.

An *x-y* stage is used to offset the autoguider position by up to 1,300 arc seconds, so the field centers of the plates remain on the five-degree grid spacing. The north guide scope remains unaltered from the original survey and can be used to hand guide plates if necessary. However, in a dark sky the autoguider system can guide accurately on a star of magnitude 9.5—approximately 0.75 magnitude fainter than the visual limit.

### 3.5 *The Night-Sky Photometer*

The photometer consists of a 3-inch (7.62-cm) telescope mounted on the body of the Oschin telescope and coupled to a photomultiplier with an S20-type detector (Hickson 1974). The field of view is equivalent to that of the survey plate and filters are used to match the spectral response to that of the plate being exposed. Since the photomultiplier has little response beyond 8000 Å, a Wratten 89B filter is used with the IVN exposures, rather than the redder RG9 filter. Both the total counts and the average count rate are recorded at the end of each exposure. The response of the system has been calibrated (Wilson, private communication) and the measurements can be transformed to the average surface brightness in magnitudes per square arc second during the exposure. We discuss these measurements further in Section 5.

### 3.6 *The Spot Sensitometer*

The original survey plates have no sensitometric calibration to permit the transformation of photographic density to intensity. Initially, a graduated step wedge, illuminated by a light source of constant intensity, was exposed onto the northern edge of the plate. However, this was replaced by a 16-spot KPNO-type sensitometer in late 1985. The sensitometer is mounted on the Oschin telescope and the calibration exposure made, via fiber optics, during the sky exposure. The spots are placed in the southwest corner of the plate, opposite the plate label. The relative intensity of each spot is set by a mask, with the intensity of the standard light source adjusted for each emulsion type by inserting different aperture stops. Table 1 gives the relative exposure for the 16 spots.

TABLE 1

Calibration Spot Sensitometry

| Log (E) | IIIa-J | IIIa-F | IVN |
|---|---|---|---|
| 0.00 | 0.04 | 0.04 | 0.03 |
| 0.18 | 0.06 | 0.05 | 0.03 |
| 0.35 | 0.08 | 0.08 | 0.03 |
| 0.54 | 0.15 | 0.12 | 0.04 |
| 0.79 | 0.30 | 0.20 | 0.04 |
| 0.96 | 0.49 | 0.32 | 0.07 |
| 1.16 | 0.83 | 0.50 | 0.11 |
| 1.34 | 1.22 | 0.73 | 0.18 |
| 1.57 | 1.93 | 1.14 | 0.35 |
| 1.75 | 2.56 | 1.56 | 0.47 |
| 1.94 | 3.15 | 2.01 | 0.88 |
| 2.11 | 3.61 | 2.53 | 1.42 |
| 2.28 | 4.04 | 3.10 | 2.19 |
| 2.44 | 4.26 | 3.54 | 3.13 |
| 2.59 | 4.48 | 3.87 | 4.05 |
| 2.72 | 4.51 | 4.06 | 4.64 |
| fog | 0.22 | 0.26 | 0.24 |

Diffuse density measurements above fog from the 16 spots of the calibration sensitometry. The results are for representative plates in each of the three passbands covered by the survey.

## 4. Plate Hypersensitization and Processing

Both IIIa-J and IIIa-F plates are hypersensitized using the same techniques, which aim to remove impurities—mainly $O_2$ and $H_2O$—from the emulsion (Miller & Nelson 1987). Until late 1988 this process consisted of first storing the plates in a pure nitrogen atmosphere for up to 2 months—the exact time was determined by monitoring the fog level on 4-inch-square test plates. Immediately before use the plate boxes were flushed of nitrogen and the plates soaked alternately in hydrogen (10 minutes) and nitrogen (50 minutes), with the cycle repeated three times. While this method produced high sensitivity (a gain in speed of a factor 5) and good uniformity in most cases, the long initial lead time produced complications, particularly in the ability to respond to changing weather conditions.

Tests by Kodak have shown that the nitrogen-soaking first stage of the hypering process can be replaced by exposing the plates to vacuum. Indeed, the latter technique is significantly more effective at inducing outgassing of the residual oxygen and moisture in the emulsion. Our current hypering process consists of placing the plate in vacuo (pressure of $10^{-4}$ torr) for several hours. Nitrogen is then flushed through the vacuum tank and the system pumped down again—this is repeated twice, with the exposure time to vacuum determined for each batch. Hydrogen gas is then introduced, with the plates soaked for 1—4 hours (again, this is batch dependent), and the vacuum/$N_2$ cycle thrice repeated. This process gives the same increased sensitivity and uniformity as nitrogen soaking and is clearly substantially more flexible. After hypering, the plates are stored in nitrogen—both in the plate boxes and in the telescope—until they are developed.

In contrast to the IIIa emulsions, the IVN plates are insensitive to moisture but are desensitized by nitrogen. After some experimentation, we have arrived at the following hypering process: the plates are soaked in a solution of silver nitrate (0.6 g $AgNO_3$ in 2.5 liters of distilled water) and ammonia (1 ml) for 5 minutes. We have found that black spots 2–4 mm in diameter (presumably aggregates of silver deposited around nodes, perhaps dust specks) form readily if we use only $AgNO_3$ solution, but adding ammonia appears to inhibit their formation. The plates are then rinsed and washed in alcohol. This last we have found essential if we are to avoid drying marks. Since the backing on the IVN plates softens in alcohol and is dissolved by ammonia, a protective frame has been devised to prevent alcohol coming in contact with the back of the plate. The plates are dried for 30–45 minutes, sitting flat on a rotating turntable under a laminar air flow. Tests have shown that the fog level increases rapidly with time on a hypered IVN plate, so each IVN plate is hypered immediately before exposing in the telescope. Moreover, the best results are obtained at ~ 17° C (Malin, private communication) rather than the standard 20° C, and the temperatures of the chemicals are maintained accordingly.

All of the plates are developed in a rotating rocker for 5 minutes in 2.5 liters of Kodak D19 solution (at 20° C), washed in stopbath solution (20 mls in 2.5 liters of filtered water) for 1 minute and fixed for 4 minutes (2 minutes in each of two fixer baths) in Kodak Rapidfix with hardener. The processed plates are rinsed in filtered water for 20–30 minutes, then treated with selenium toner, and washed for a further 30 minutes before drying. The last process has been found to inhibit the formation of gold spot disease on type IIIa plates (although none of the older, untreated Palomar plates have been found to be afflicted by this problem). The typical gain in speed obtained by these hypersensitizing techniques is a factor of 5–10 for the IIIa plates and up to a factor of 100 for the IVN plates. Examples of the characteristic curves of the processed plates are tabulated in Table 1 and plotted in Figure 3.

## 5. Plate Quality

All of the plates are inspected both at the telescope (by the mountain staff) and in Pasadena (by I.N.R.). Plates are rejected if there is an unacceptable degree of image elongation; if there are particularly obvious cosmetic defects (several aeroplane trails, emulsion flaws, etc.); if there are significant nonuniformities in the response; if the photographic (clear plate) fog density lies outside the range

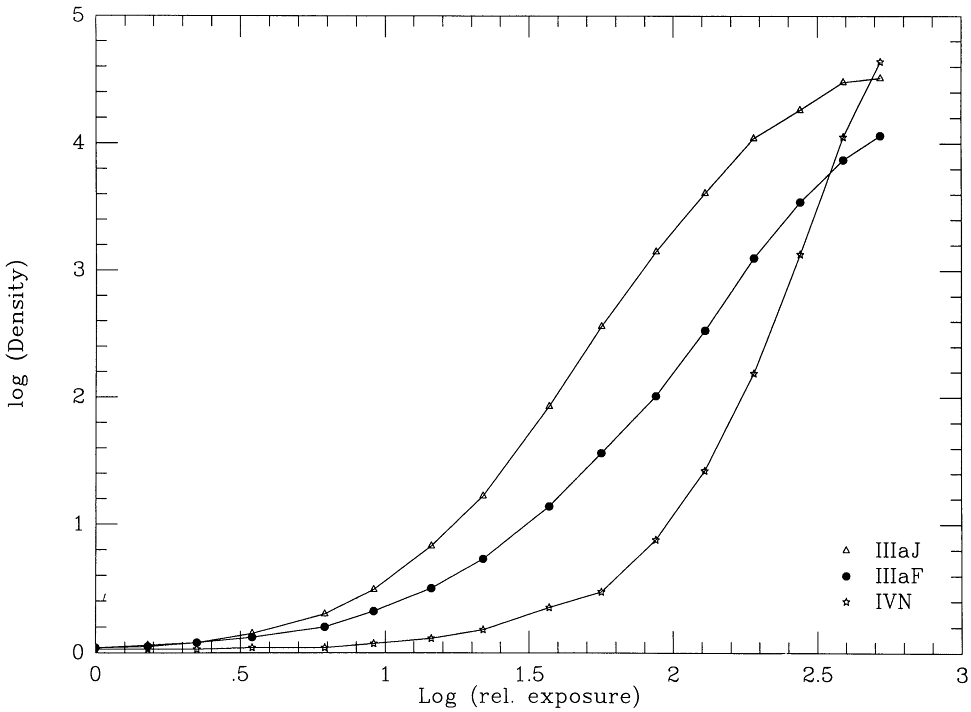


FIG. 3–Typical HD curves for the three emulsions used in the POSS II survey.

0.1 to 0.4; if the sky-background level exceeds a density of 1.7 (except for some Milky Way fields); or if the images exceed 40 microns (3 arc seconds) in size. Obviously there is a certain degree of subjectivity in the plate grading, but we believe we have minimized this by having two independent inspections. The inspection data, including the spot sensitometry, are kept in a computer logfile at Caltech.

As in the original survey, the accepted plates are graded at several levels—A, B, C1, and C2. Category C2 plates, although representing an improvement over the POSS I material, are affected by significant defects; category C1 plates have noticeable, but generally unimportant, cosmetic defects; and category B plates have very minor blemishes. It is our intention to replace at least all C2 plates before the completion of the survey. We describe briefly a number of the more common minor defects.

(a) aeroplane trails—approximately 20% of the plates are affected. We have rejected the worst cases (B52s in formation-flying exercises, etc.) but, given the number of plates affected, we have downgraded those with only a single, relatively low-brightness aircraft trail. While aesthetically displeasing, these trails cover a very small fraction of the plate and are of no hindrance to the majority of scientific investigations.

(b) satellite trails—given the high concentration of objects in orbit over the U.S., most plates taken near twilight have at least one satellite trail.

(c) image elongation—both astigmatism in the corrector (see Section 3.1) and differential refraction/field rotation can lead to noncircular images. At present we have no simple mechanism for adjusting the polar-axis alignment to allow for the latter effect (see Wallace & Tritton 1979). We have rejected plates where the elongation is unacceptable ($\geq 20\%$).

(d) diffuse spots—these low-surface-brightness features appear on a small number of IIIa-J and a very few IIIa-F plates, mimicking low surface brightness dwarf galaxies. The cause appears to be low-level static discharges within the plateholder. Again, it is our intention to replace all plates so affected.

We noted above that the night-sky photometer provides a measurement of the sky brightness (in the appropriate passband) during each exposure. These observations have been calibrated using first-magnitude stars (C. Wilson, private communication) and Figure 4 shows the data accumulated in the J and F passbands since 1985. (The lower-sensitivity IVN plates are taken in bright time with varying degrees of moonlight providing the dominant contribution to the sky brightness.) We have allowed for the contribution made by Galactic stars, using Roach & Gordon's 1973 surface-brightness map for stars in the magnitude range $6 < V < 18$ and accounting for brighter stars on an individual basis. Fields at galactic latitudes below $17\overset{\circ}{.}5$ are omitted from the figures.

The data span a significant range in surface brightness —nearly a factor of three in J. While this partly reflects variation due to natural causes, such as the zodiacal light and terrestrial airglow—the F passband includes the

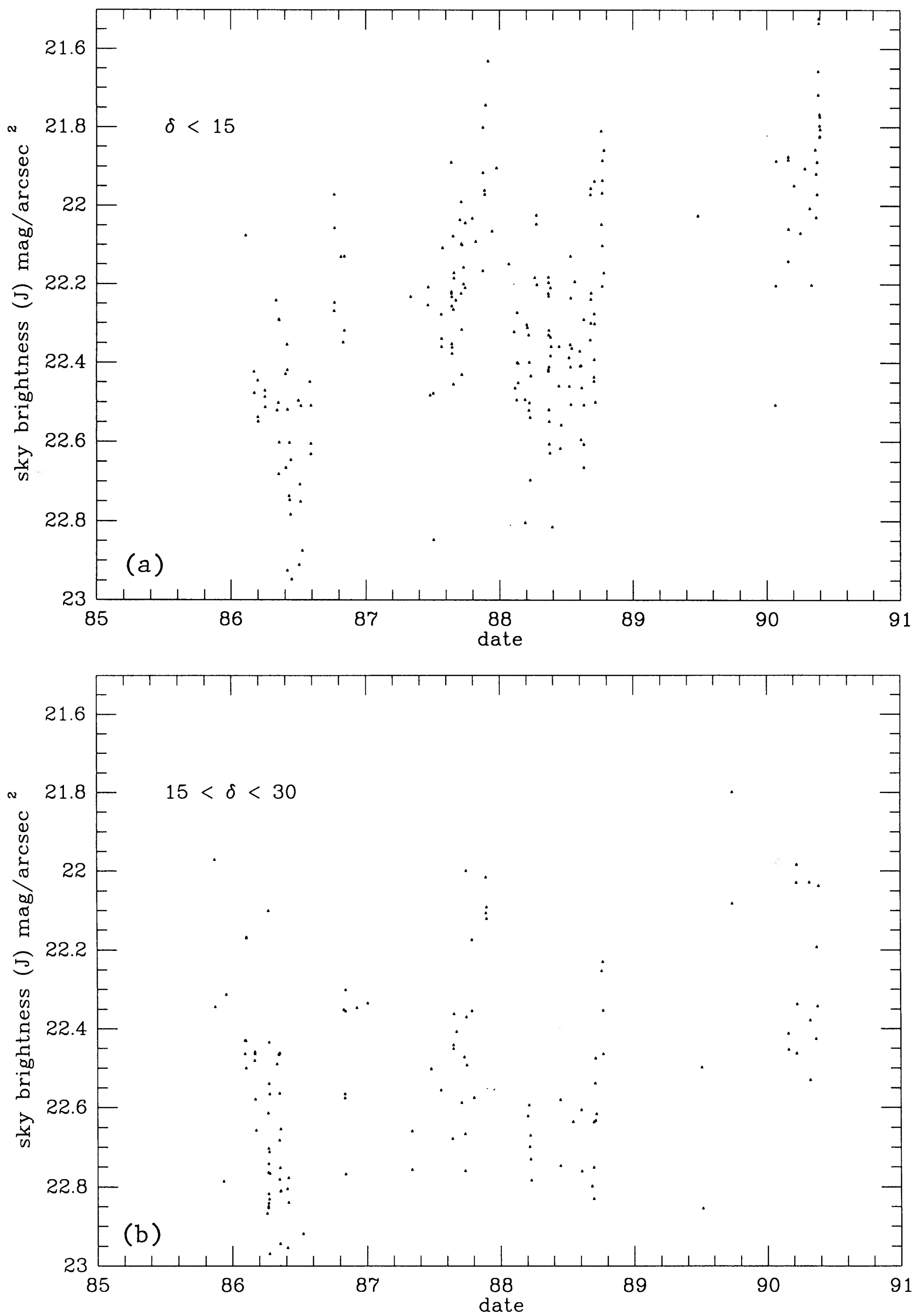


FIG. 4 (a and b)–Sky brightness as a function of time as measured by the night-sky photometer on the Oschin Schmidt. We have divided the data into four declination zones. Figures 4a–d present the observations in the J band while Figures 4e–h show the F band observations. The IVN plates are taken with varying degrees of moonlight.

oxygen λ6300 lines—light pollution accounts for most of the scatter. We have divided our data into four declination zones, and it is evident that the average sky brightness is highest in the lowest declination zone—particularly in J. It is also clear that the lower envelope rises over the four years covered—that is, the darkest nights, when coastal cloud obscures much of the San Diego/Riverside areas, are less dark now than in 1985. This probably mainly reflects the increase in solar activity over the last 5 years, but there may also be some contribution from the substantially increased population in this area of southern California—it is simply getting more difficult to obscure all of the local cities. Most areas surrounding Palomar Observatory have adopted low-pressure sodium lighting

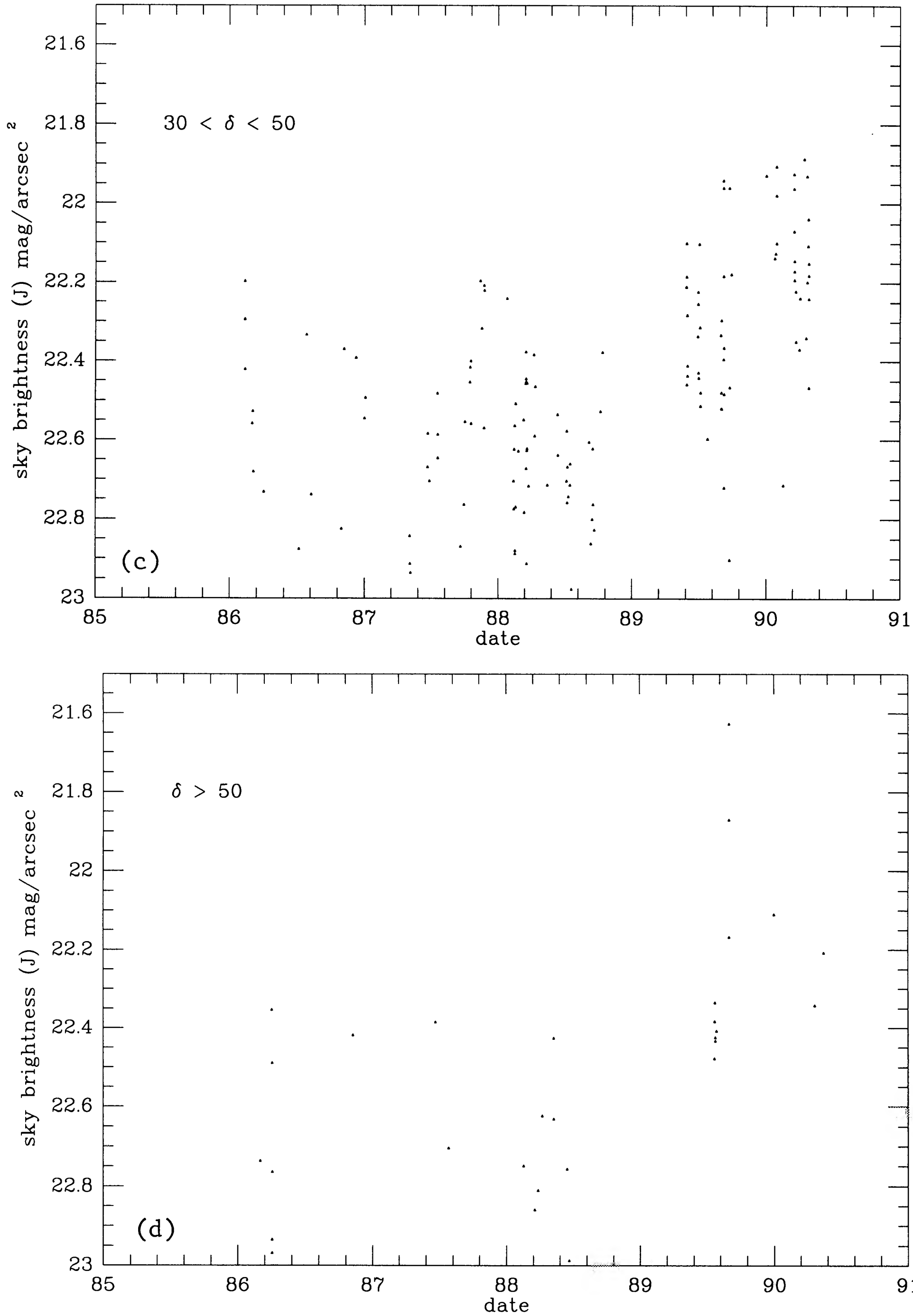


FIG. 4–Continued (c and d).

—the Na D lines lie outwith both J and F bands, so without these ordinances conditions at Palomar would be significantly worse.

The variation in sky brightness clearly has to be taken into account in determining the exposure times suitable for survey plates. The optimum signal-to-noise ratio for IIIa emulsion plates is attained at densities of ~ 1.1—1.3 above fog, equivalent to total densities of ~ 1.3—1.5. Given the sky-brightness measurements by the photometer, we can estimate the appropriate exposure time to attain this background level. However, the limiting magnitude (for stars) depends on the total exposure time, and on the brightest nights we can tolerate no more than 35 minutes exposure time. To maintain a higher degree of uniformity, J plates are taken only if the optimum exposure time is at least 50 minutes.

Typical limiting magnitudes for the POSS II plates are

$$B_J(\mathrm{lim}) = 22.5 \text{ mag} \ ,$$

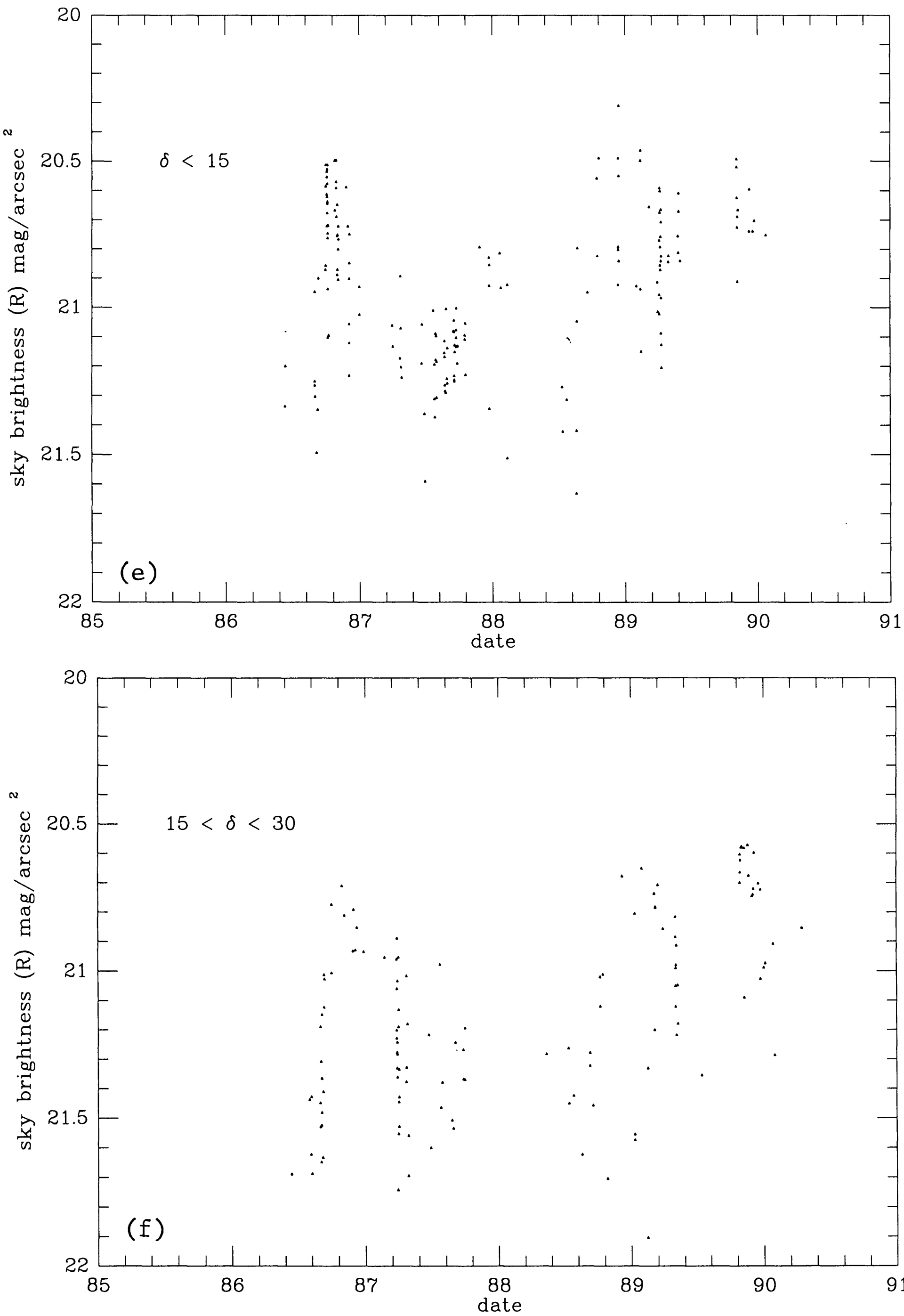


FIG. 4–Continued (e and f).

$$R_c(\text{lim}) = 20.8\ \text{mag} \ ,$$

$$I_c(\text{lim}) = 19.5\ \text{mag} \ .$$

These have been calibrated using CCD sequences by A. Picard (private communication). The latter two magnitudes are on the Cousins system, while the first is on the system defined by Blair & Gilmore 1982, viz.

$$B_J = B - 0.28 \times (B - V) \ .$$

These limits are for stellar objects in good seeing ($\leq 1.5$ arc seconds) and can vary by up to $\pm 0.4$ magnitude from plate to plate. Figure 5 shows the distribution of limiting magnitude for 17 IIIa-F plates (both accepted and rejected) calibrated by Picard. Both plates with $R_c$(lim) $<20.25$ are rejected from the survey.

As an illustration of the improved quality of the new sky-survey plates, Figure 6 compares POSS I O and POSS II J photographs of several systems from the *Atlas*

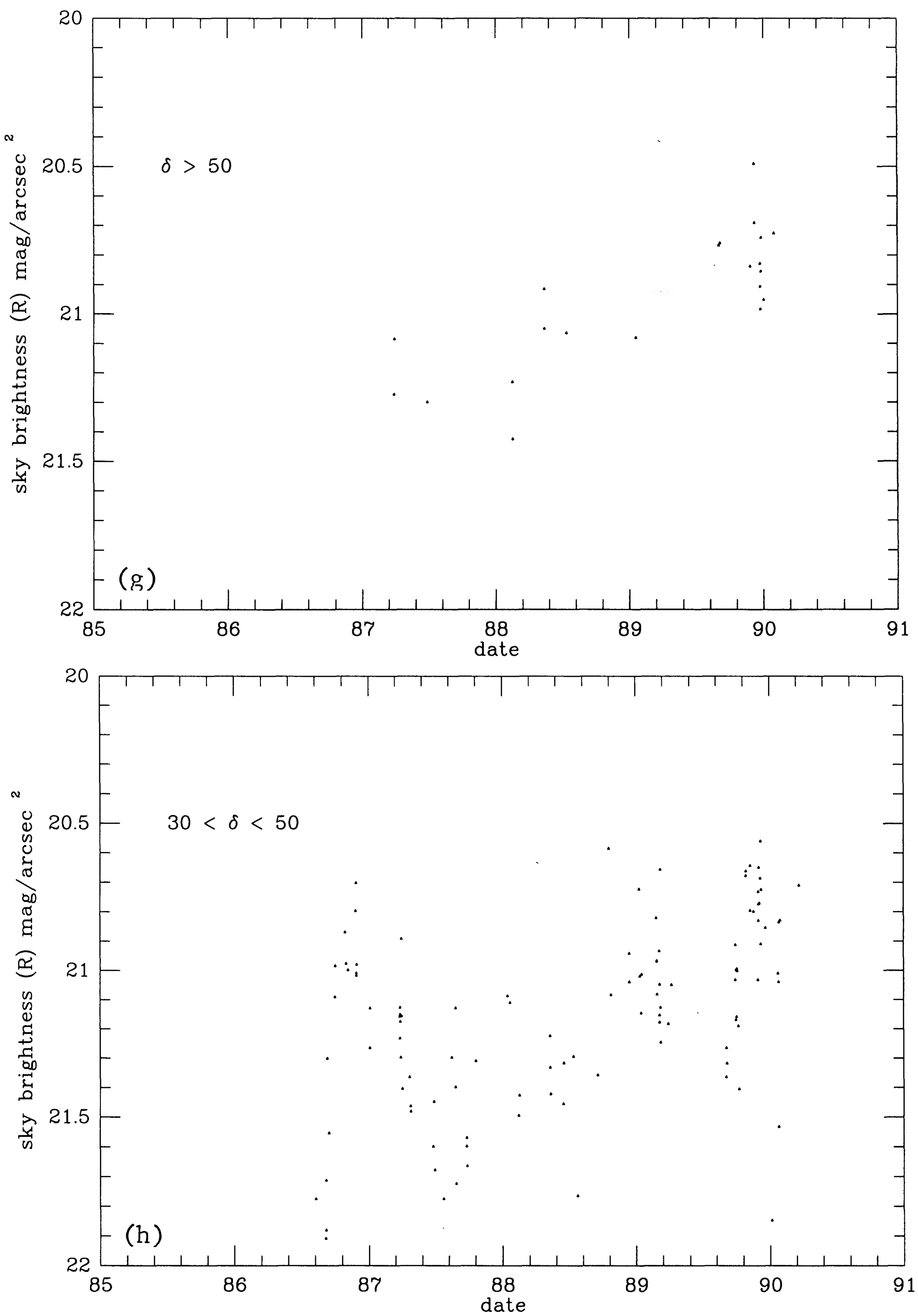


FIG. 4–Continued (g and h).

*of Peculiar Galaxies* (Arp 1966). The increased signal-to-noise ratio due to the finer-grain emulsions is particularly well illustrated in the interacting system Arp 319. We have compared our POSS II plates with UKST J and F plates of several equatorial fields. The limiting magnitudes are similar in both passbands, and our data for the IVN plates suggest that these also are comparable. Thus, the completion of the POSS II and UKST survey of the southern equatorial survey will provide near-uniform coverage of the whole sky to $B_J \sim 22.5$ magnitudes.

## 6. Summary

We have described the main characteristics of the second Palomar Sky Survey, which is being taken using IIIa-J and IIIa-F, and IVN plates on the Palomar Oschin telescope. The survey will be made available to the astronomical community in the form of film and glass copies which, following a recent agreement between the Califor-

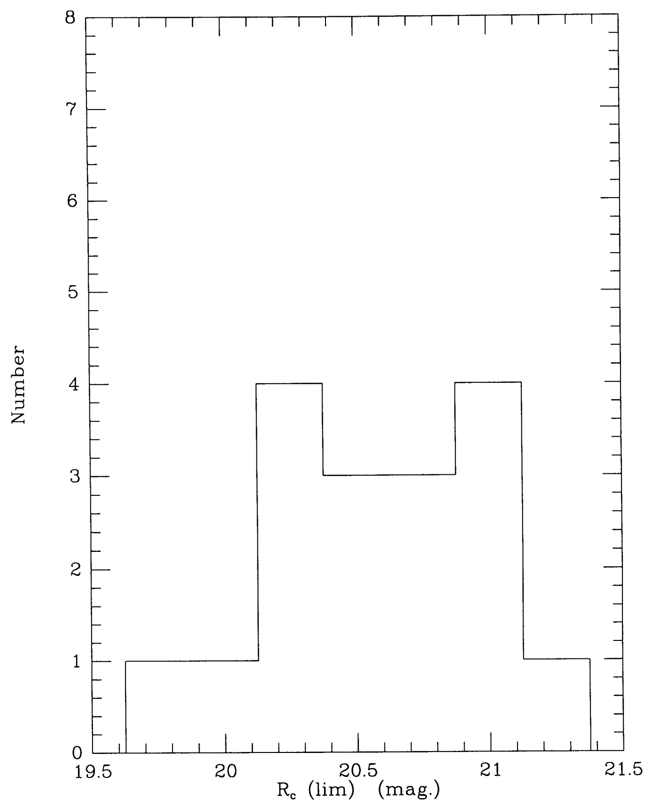


FIG. 5–The distribution of limiting magnitude for 17 IIIa-F plates. These data have been calibrated by A. Picard.

nia Institute of Technology and the European Southern Observatory, will be produced by the European Southern Observatory. Recent years have seen the development of fast plate-scanning machines, and a digitized version of POSS II will be made, although the full details remain to be settled. In addition, the U.S. Naval Observatory will use a scanning machine similar to the Kitt Peak scanning densitometer designed by Monet (described in Saha, Monet & Seitzer 1986) to carry out astrometry of the original plates. As described above, short-exposure plates will be used to set these measurements on the fundamental system, while the addition of measurements of POSS I plates will provide a proper-motion catalog for the northern sky.

At present (February 1991) we have obtained 802 plates of acceptable quality for inclusion in the survey. Three hundred and forty-six of these plates were obtained in the preceding 12 months out of a total of 473 plates taken—that is an acceptance rate of 73%. We can extrapolate these data to estimate the completion date of the survey. However, before doing so several factors should be borne in mind: first, most of the plates taken to date are J and F plates, and the lower-sensitivity IVN require slightly longer exposures—90+ minutes as against 50–70 minutes for the J plates and 70–90 minutes for the F plates; second, approximately 10% of the accepted plates have minor defects and it is our intention to replace these if at all possible; and third, on the positive side, the past four winters have been unusually bad—both at Palomar and other U.S. observatories—and, with the long winter nights, improved conditions could substantially shorten the survey. Making due allowance for these factors, we would estimate that, with the possible exception of a few recalcitrant fields, the POSS II survey will be finished in five to seven years.

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*Note added in proof.* We have recently started using an ST-4 Star Tracker/Imaging camera, purchased from Santa Barbara Instrument Group, to augment the autoguider described in Section 3.4. This system allows guiding on stars fainter than $V = 10.0$ magnitude.

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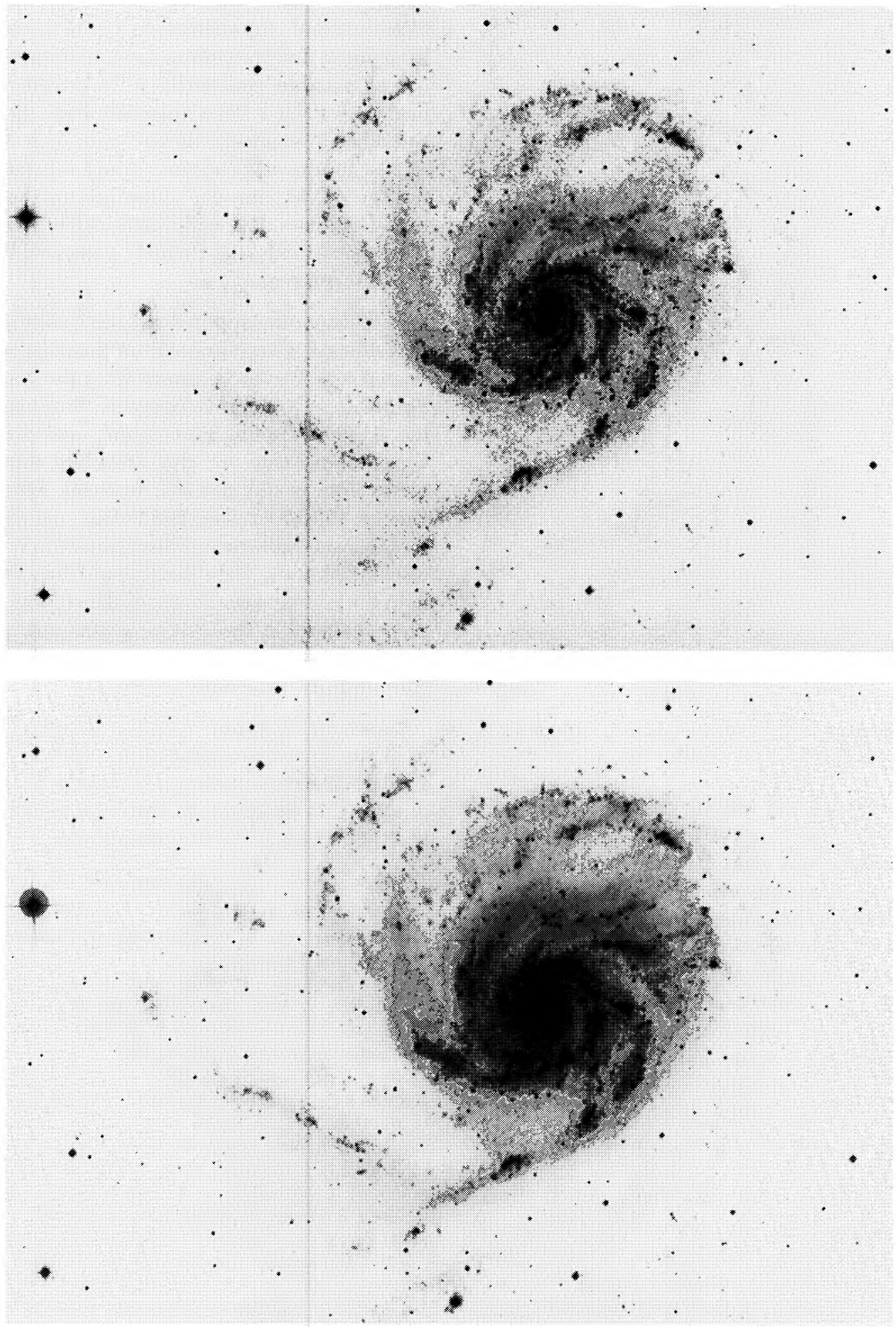
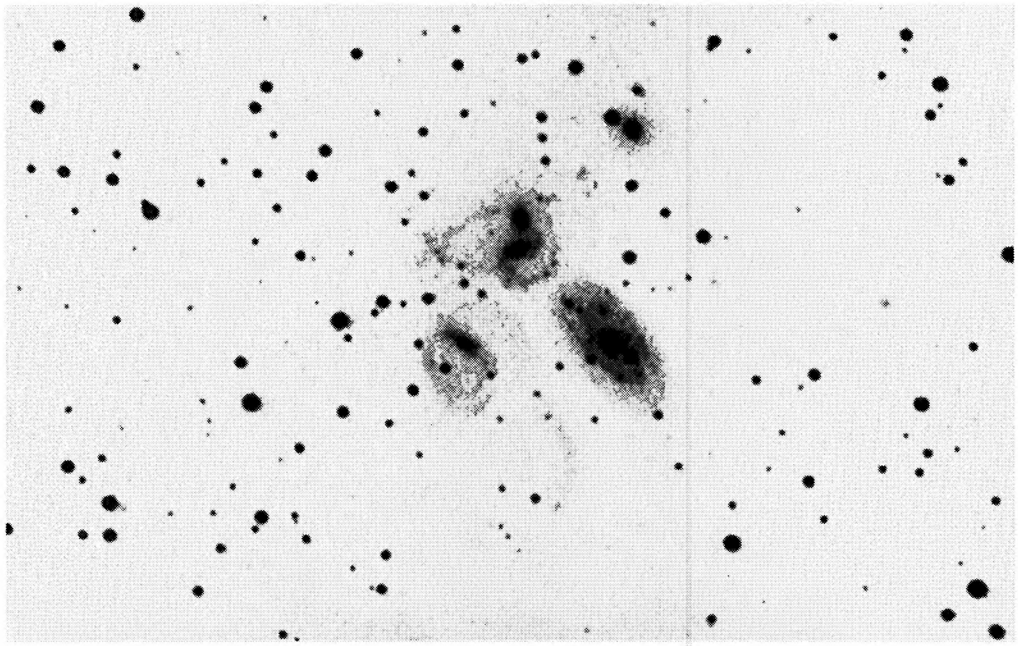


FIG. 6–A comparison between the first and second sky surveys. The system shown here is M 101 (Arp 26). Upper, POSS I; lower, POSS II. In each case we compare POSS I O against POSS II J. Note the substantially lower noise in the sky background due to the finer grain of the IIIa-J emulsion.



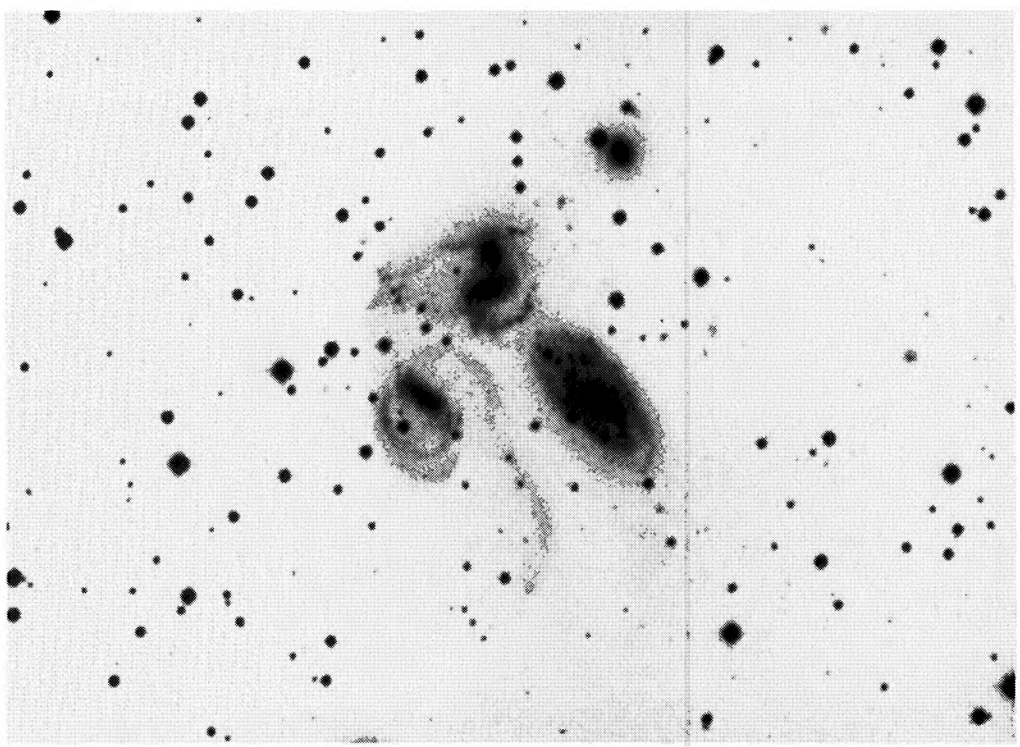


FIG. 6–A comparison between the first and second sky surveys. The system shown here is NGC 7331 and companions. Upper, POSS I; lower, POSS II. In each case we compare POSS I O against POSS II J. Note the substantially lower noise in the sky background due to the finer grain of the IIIa-J emulsion.

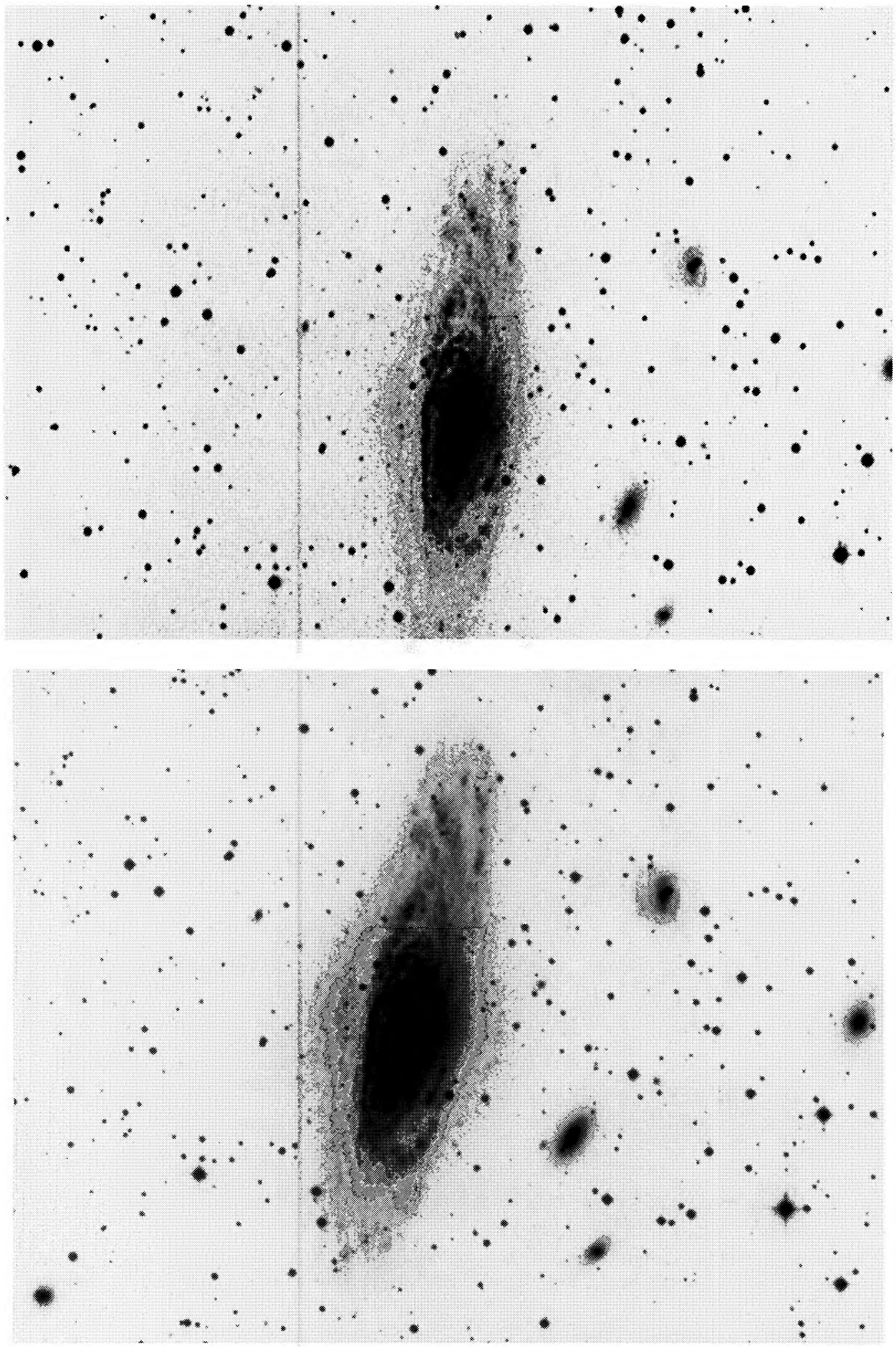


FIG. 6–A comparison between the first and second sky surveys. The system shown here is the interacting system Arp 319 (NGC 7317/18/19). Upper, POSS I; lower POSS II. In each case we compare POSS I O against POSS II J. Note the substantially lower noise in the sky background due to the finer grain of the IIIa-J emulsion.